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July 9, 1999

Ms. Magalie Roman Salas, Secretary
Federal Communications Commission
The Portals, TW-A325
445 12th Street, S.W.
Washington, DC 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Re: *Ex parte* Notification - Time Domain Corporation
ET Docket No. 98-153

Dear Ms. Salas:

On July 8, 1999, Ralph Petroff, Larry Fullerton, and Rachel Reinhardt of Time Domain Corporation and I met with Julius Knapp, Chief of the Policy and Rules Division of the Office of Engineering and Technology (OET), Karen Rackley, Chief of OET's Technical Rules Branch, Rodney Conway, an electrical engineer in the Branch. We discussed the current status of the Commission's *Inquiry* into ultra-wideband and the possibility of a rule making that would follow in response to the record made in the *Inquiry*.

We left behind a copy of an article from *MD Computing* that discusses ultra-wideband technology. A copy is enclosed.

Should any questions arise concerning this matter, please contact me.

Respectfully,

David E. Hilliard

David E. Hilliard
Counsel for Time Domain Corporation

Enclosure
cc: Messrs. Knapp, and Conway; Ms. Rackley

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March/April 1999 Vol.16, No. 2

MD Computing

The Leading Edge in Medical and Healthcare Informatics

TECH TALK

Catching the Wave
BREAKTHROUGHS in WIRELESS TECHNOLOGY

JOHN S. GAGE, M.D.

With exciting new technologies like time domain transmission just around the corner, the wireless future of medicine has never been brighter.

t's only five digits long, but it is the stepping off point for enormous changes in medicine : 802.11- the institute of Electrical and Electronics Engineers (IEEE) standard for wireless communication using the 2.4 GHz ISM (Industrial, Scientific, and Medical) band. IEEE 802.11 promises to eliminate many of the cables coming from the backs of our desktop computers by using radio waves to transmit information rather than electrical cabling. Within a few years, this technological breakthrough will permit truly mobile computing at home and in the workplace, allowing doctors and other medical personnel to walk the hospital halls with portable computers, visit bedsides, and log in patient information. This article discusses two additional wireless local area network initiatives built around the 2.4 GHz band and focuses on time-domain modulation- a new technology of such extraordinary intellectual and practical interest that it may soon revolutionize wireless communications, making the current technology obsolete.

A desktop computer with a separate scanner, modem, palmtop, fax, keyboard, printer and perhaps a network connection, is a very hairy business: cables everywhere collecting dust and impeding traffic. So-called portables are even worse, because they must be connected and disconnected to all this paraphernalia each time they are used. To get away from this computer-generated spaghetti, Intel, IBM, and several cellular phone makers have developed a standard called "Bluetooth," which replaces cables with radio waves using the 2.4 GHz band. Each device would contain a microchip measuring less than one square centimeter containing everything necessary for short-range (10 meters) wireless communication. As an added, voice communication would be possible using voice recognition and voice commands. Although it is not yet commercially available- and has yet to strike the fancy of Microsoft-Bluetooth would cost about $5 per device. Information can be found at www.bluetooth.com

It seems, though, that a company based in Vancouver, Washington has beaten the heavyweights to the wireless punch. Diamond Multimedia Systems (www.diamondmm.com) is already marketing a wireless local area network for the home and small office, costing somewhat less than $100 per device. It's a network card that permits multiple computers within 150 feet of one another to communicate and share resources, such as Internet access and printing. The technology in Diamond's system was created by a small 1997 start-up called Alation (www.alation.com) that has independently developed another spread-spectrum, frequency-hopping specification in the 2.4 GHz band they call the HomeCast Open Protocol or HOP.

While this new wireless technology is on the verge of becoming standard issue, and extraordinarily interesting technological breakthrough-time-domain transmission-promises an even brighter wireless future. Before getting into this, though, it's important to review a brief history of technological events relevant to the development of radio communication.

For many centuries, mankind has attached great importance to the accurate measurement of time. For example, prior to the invention of modem, nonpendulum clocks, mariners at sea were unable to reliably determine their longitude (think about a pendulum on ship at sea !). Latitude was easy : They knew how far north above the equator they were simply by measuring the angle of the sun over the horizon; but longitude, the east-west dimension, was a much tougher proposition. Thousands of lives were lost because hopelessly lost due to this inability to accurately determine longitude. The need for accurate chronometers was such an intense preoccupation that the British Admiralty offered a large reward to the individual who could perfect a clock that could accurately tell time at sea. As chronicled in Dava Sobel's marvelous book, *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time* (Penguin), it was John Harrison a carpenter and self-taught clock maker, who finally build one in 1759. Harrison won the reward and provided the British Admiralty with the means to navigate safely over the world's oceans.

What the relation between time and longitude, you may ask ? If a mariner sets out from London time, then, by determining noon at a particular position (the moment when the sun highest in the sky), that can be compared with the time in London. If noon at sea occurs at 1 p.m. in London, then the mariner knows that the ship is 1 hour (or 360.24 degrees) west of the home port. But the clock must be accurate. If it gains or loses even a minute or two per day, the calculation quickly become worthless. John Harrison's clocks were accurate to within 1/5th of a second per day and calculated longitude to within a few miles over long voyages. The inventor had paved the way for the development of modern time-measurement techniques that would ultimately lead to extraordinary innovations in radio communications.

> If John Harrison's clock had cost a million pounds, it would not have realistically solved the problem, because no one would have dredged up the cash to pay for it.

More recently, the United States Air Force put 24 Navstar satellites-each the size of a large automobile and weighting about 1,900 pounds-into orbit 11,000 miles above the earth. This took place over a 15-year period from 1978 to 1993 at a cost of more than $12 billion. The global positioning system (GPS) uses atomic clocks aboard these satellites to broadcast a time signal is received from the time it is sent and multiplying the difference by the speed of light, GPS receivers can determine the distance to several satellites, and, using triangulation, determine their own location to within 50 feet or so. Thus, starting with John Harrison, improvements in timekeeping over the past two centuries have led directly to corresponding improvements in out ability to determine exact locations on earth by several orders of magnitude. As we shall see, this made a tremendous advance radio communication possible.

At this point, the inquisitive reader might ask: "Are there atomic clocks in GPS receivers that make them so precise ?" After all, the accuracy of the distance calculation between satellite and earth is dependent on the accuracy of the time the signal is sent and received. Well, the answer is no; it turns out that GPS receivers have cheap quartz clocks that keep their cost to under $100 (surely it would take a remarkable yard sale to find an atomic clock at that price). However, by receiving the signal of a fourth satellite-in addition to the three satellites whose distance from the receiver is being measured through triangulation-the GPS receiver can improve the accuracy of its lowly quartz clock from one second in a thousand years to that of the more sophisticated clocks abroad the satellites.

But the question of cost is a pivotal one and bears directly on the technology that will replace IEEE 802.11. It is not simply important to measure time accurately; it is equally important to measure it cheaply. If John Harrison's clock had cost a million pounds, it would not have realistically solved the problem of measuring longitude, because no navy at that time would have dredged up the cash to pay for it. And, as we have seen above, while IBM and others seek to develop a $5 radio-communication chip for the home computer, Diamond Multimedia Systems has already developed a $100 network card that accomplishes the same thing that they will undoubtedly profit from until the cheaper device comes on line. The only question is, how many home computer users will want to spend an additional $100 for wireless communication ? Put another way, GPS would just be three letters of the alphabet if cheap quartz clocks were not readily- and cheaply-available. Still, it should be noted parenthetically that the GPS "solution" to the problem of inexpensive time measurements is not really inexpensive. Although the cost-effective use of quartz clocks is a bargain, the $12 billion worth of satellites and the additional few billion more dollars for an Air Force base in California devoted to the care and feeding of those satellites is not exactly cheap. Surely, the soon-to-be ubiquitous GPS receiver is the most heavily government-subsidized consumer technology on earth. ("Free-enterprise" and "government-interference" fanatics take note.)

Like the world's oil reserves, rainforests, and wetlands, the spectrum (3KHz to 300 GHz) is a natural resource that mankind is rapidly depleting.

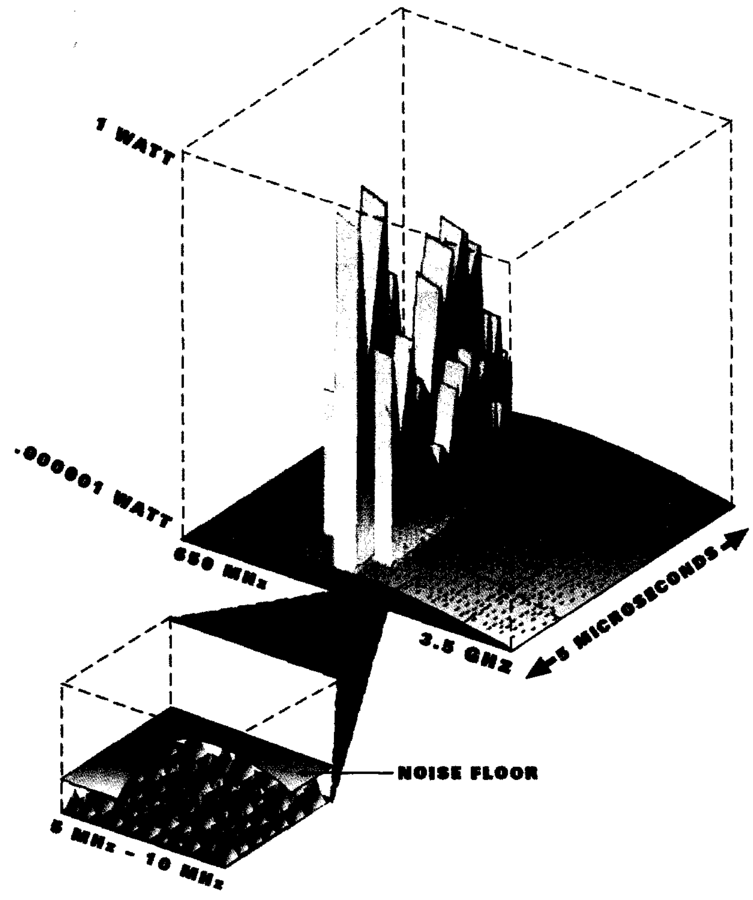
In addition to time measurement, the development of wireless communications has also been driven by the increasing usage of the radio spectrum. Like the world's oil reserves, rainforests, and wetlands, the spectrum (3 KHz to 300 GHz) is a natural resource that mankind is rapidly depleting. New uses, such as IEEE 802.11, are multiplying much faster than our ability to allocate a fixed number of frequencies for them. Part of the reason is that for the past 100 years, which encompasses the entire history of commercial radio, all radio usage has been tied to specific frequencies via either the amplitude modulation of a specific frequency, or frequency modulation around a specific carried frequency to find the radio station we want. The problem facing mankind is that the dial is getting more and more crowded as there are fewer and fewer frequencies available.

Starting in 1987, and inventor named Larry Fullerton, a latter-day John Harrison, looked into using the radio spectrum in a way that was different from traditional frequency tuning. His idea was to use individual radio waves, or "Gaussian monocycles," to carry information. This would effectively transform radio communication into a digital medium, with each monocycle corresponding to a single bit of information. In Fullerton's conception, information would be extracted from a series of individual monocycles by measuring the variation in the time between their transmission; zeroes would correspond to waves that arrive slightly late-a technique he referred to as "time-domain" modulation.

Here, then, is a method of transmitting digital information that is dependent on the accurate measurement of very small periods of time : the intervals between when the individuals waves are supported to arrive and when they actually arrive. How short are these intervals ? Typically they are on the order of a few picoseconds (trillionths of a second). The advantages of employing Gaussian monocycles instead of traditional, frequency-based transmissions are considerable. Let us refer back to IEEE 802.11, Bluetooth, and HOP. All these techniques are based on the ISM 2.4 GHz band and promise bandwidths of 1 or, at best, 10-megabits-per-second. If, however, one is sending Gaussian monocycles at 2.4 GHz, then the theoretical limit of the speed of transmission is on the order of a million times greater. Even if these theoretical limits are not achieved, this method still allows for the transmission of many thousands of times more information i a particular time period than traditional frequency techniques.

Suppose, on the other hand, that instead of using the 2.4 GHz band, we were to use a lower frequency for our Gaussian monocycles. As long as we didn't lower the frequency by many orders of magnitude, we would still greatly increase our bandwidth over traditional transmission frequencies; however, by lowering the frequency just a little, we could greatly improve the ability of the transmission to penetrate solid objects, such as walls and other barriers found in most buildings. Hence, while maintaining greatly increased bandwidth, we are at the same time using time-domain transmissions to tremendously increase the range of broadcasts in the office and home environments.

So is it possible to use lower frequencies than 2.4 GHz without requiring each user of a time-domain device to obtain a license from the FCC ? Unlicensed operation is, after all, the great attraction of the 2.4 GHz band. To answer this question, one must look at the exact nature of the Gaussian monocycle. In essence, it is the radio frequency equivalent of the acoustic "click-the shortest possible sound. One might produce it by taking a pure frequency tone, middle C for example, and progressively shortening its duration. As this happened, however, one would notice that



Time-domain transmission could revolutionize the field of wireless communications. As shown here, conventional signals transmitted in the frequency domain are highly "visible" electronically because all the power is packed into a narrow bandwidth. However, time-domain modulation transmits millions of unstructurred coded monocycles (cyclets) per second across an ultrawide band whose emissions are industringuable from noise- a virtually undetectable communications link. © Time Domain Corporation

the frequency of the sound, instead of remaining pure, would start to "spread" over adjacent frequencies until, at the limit, it transmitted energy over nearly all the audible frequencies. Clicks contain all those frequencies. In the case of the Gaussian monocycle, even though one may transmit them at 2.4 GHz, energy will be radiated over several adjacent gigahertz of radio spectrum due to the short, click-like, nature of the monocycles. At first, this may seem like a drawback; and, in fact, the FCC is currently investigating exactly how to treat time-domain transmission. But because the power of the transmission is spread over several gigahertz of radio spectrum, at any specific frequency it is indistinguishable from background noise, making it exceedingly difficult to detect, intercept, or interfere with. Licensing such transmissions would be senseless because no one would be able to detect them or experience interference from them.

Time-domain technology is being developed by (Surprise !) a company called Time Domain, Inc. (www.time-domain.com). The principle stumbling block to commercializing it, aside from the bureaucratic wrangling of the FCC, is developing a cheap, integrated circuit capable of measuring the extraordinary short time intervals involved. Time Domain is using IBM's Silicon Germanium lab facilities to create the first prototype of such a circuit.

As this technology matures, we can look forward to a wireless world have now opened the door to medical techniques that are currently unimaginable-but which, no doubt, will save lives as well. MD COMPUTING

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